

SenseWeb: Shared Macro-scopes for Scientific Exploration

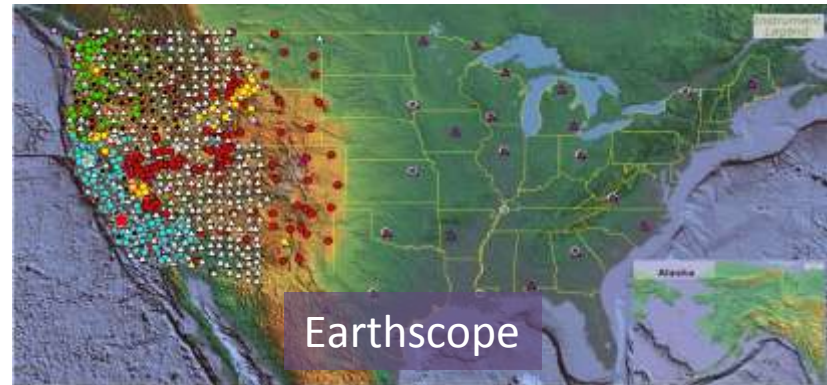
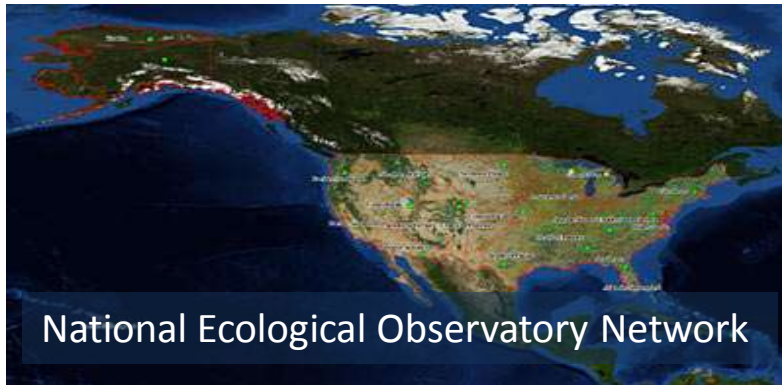
Aman Kansal*, Suman Nath, Feng Zhao

Networked Embedded Computing

Microsoft Research

Instrumentation Is Hard

1. Share data via central archives
 - Swivel, Sloan sky survey, Fluxdata.org, BWC Data Server
2. Build macro-scopes: NEON, Earthscope
 - Can only address a few domains



3. Share all instrumentation: SenseWeb

Key Idea: Wikipedia of Sensors

Everyone deploys their own sensor network

Share all sensors using SenseWeb

Everyone can run more experiments!



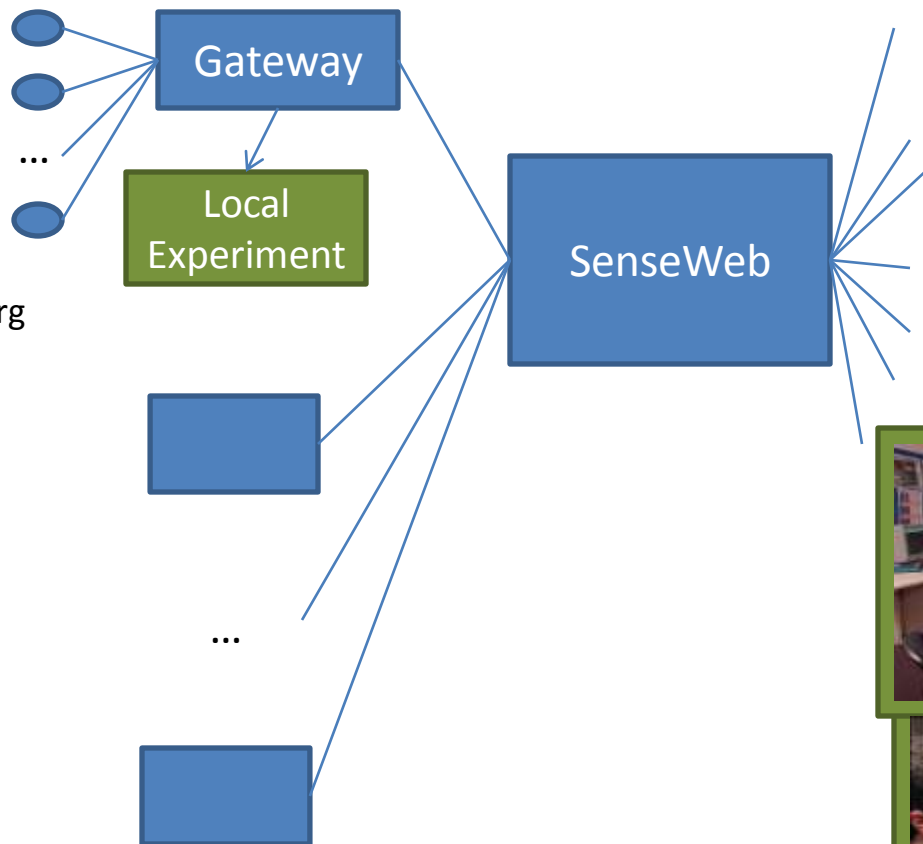
Soil Ecologists
Eg. LifeUnderYourFeet.org



USGS sensors



Other labs...



Outline



Case Study

- SeaMonster: Glacier, hydrology, and oceanographic exploration
- SensorMap Demo



SenseWeb Architecture

- Global or selective sensor stream sharing



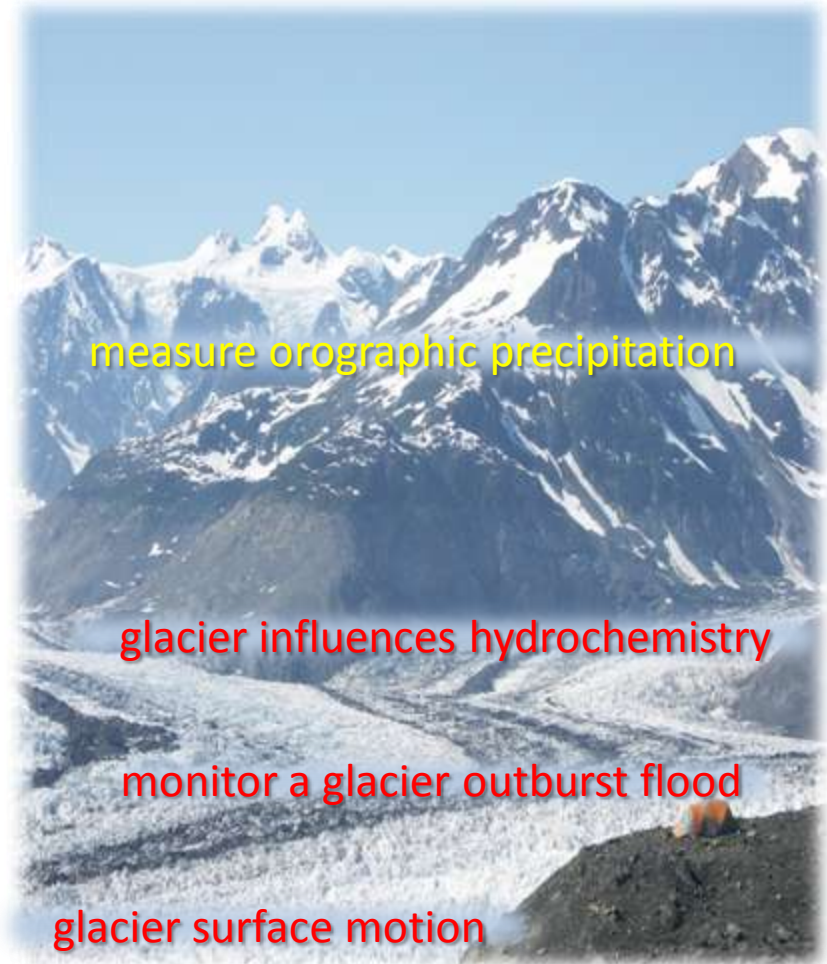
Usage Examples

- Projects using SenseWeb

A Case Study: SeaMonster

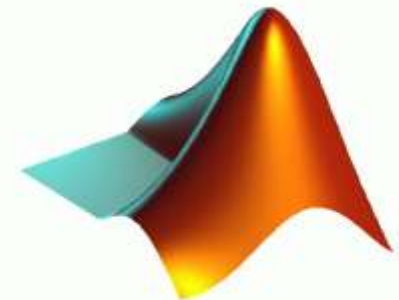


- South East Alaska MOonitoring Network for Science, Telecommunications, Education, and Research
 - Collaborative environmental science with large volumes of environmental data
 - NASA, NOAA, Univ. of Alaska, Vexcel-Microsoft



SeaMonster: Generation 1

- Deploy sensors with local storage
- Physically visit for data collection
- Process archived data offline



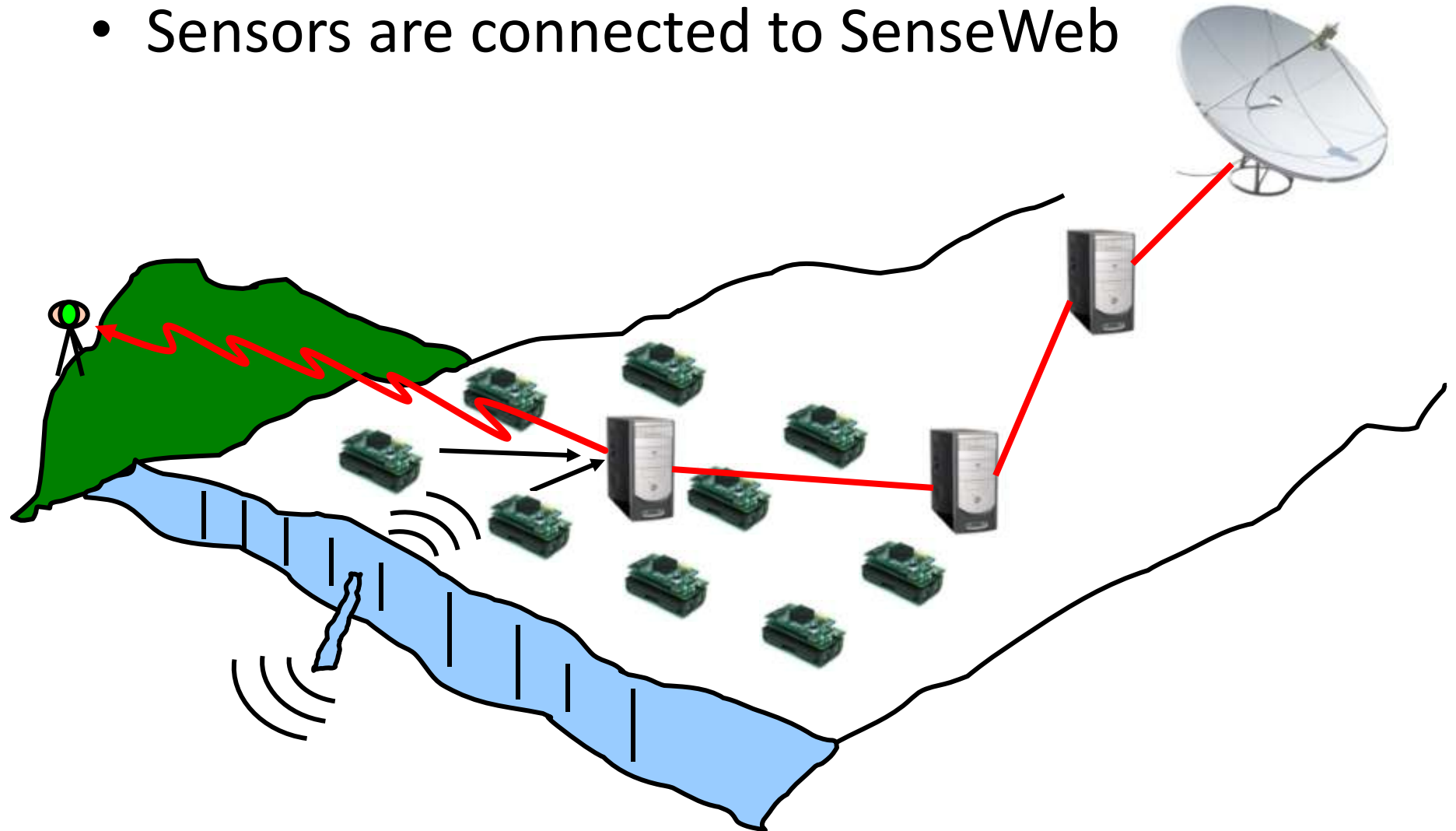
Generation 1

- Problems:
 - No real time feedback
 - No data if the device fails
 - No interactivity



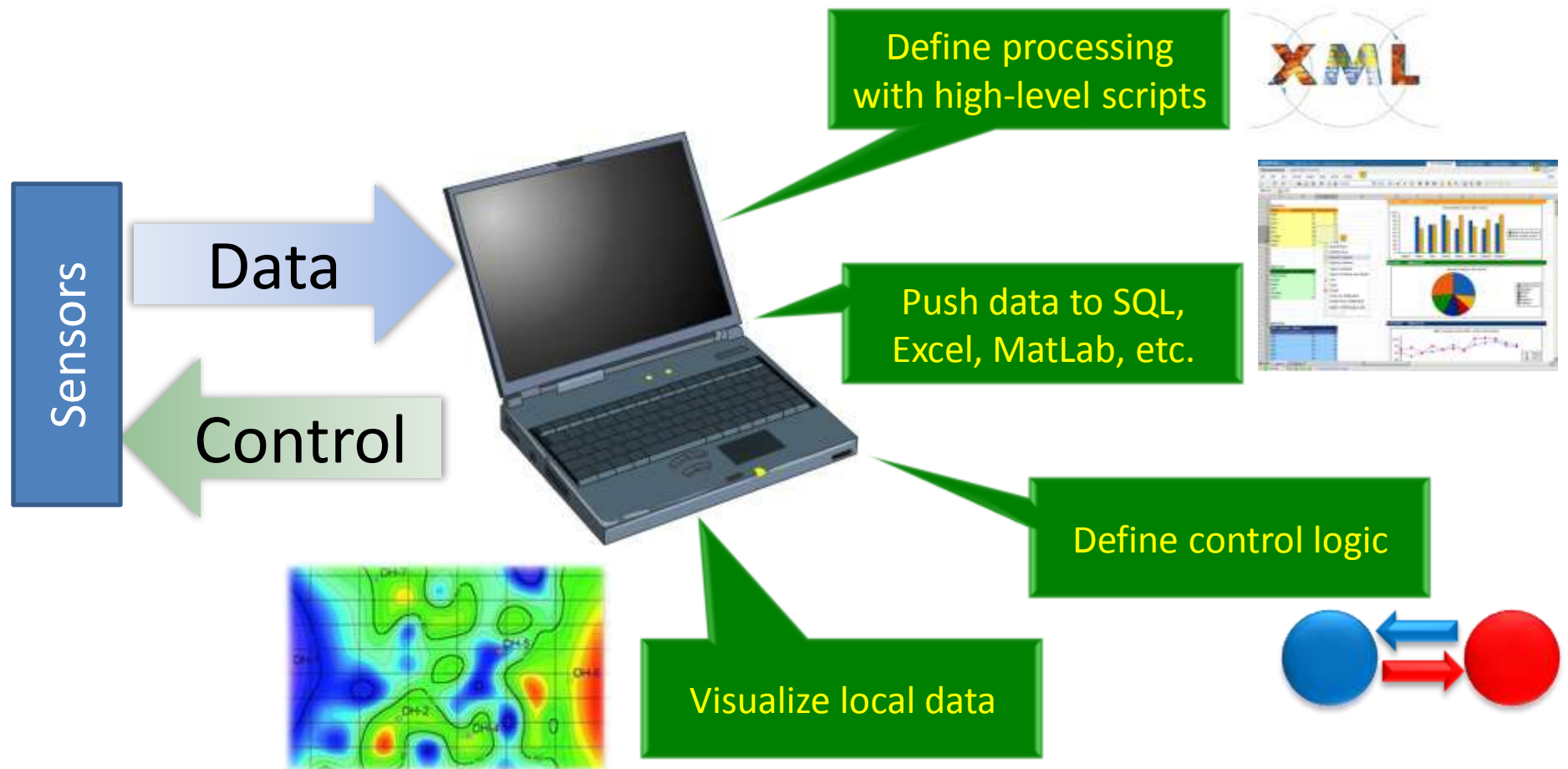
SeaMonster: Generation 2

- Sensors are connected to SenseWeb



MSRSense

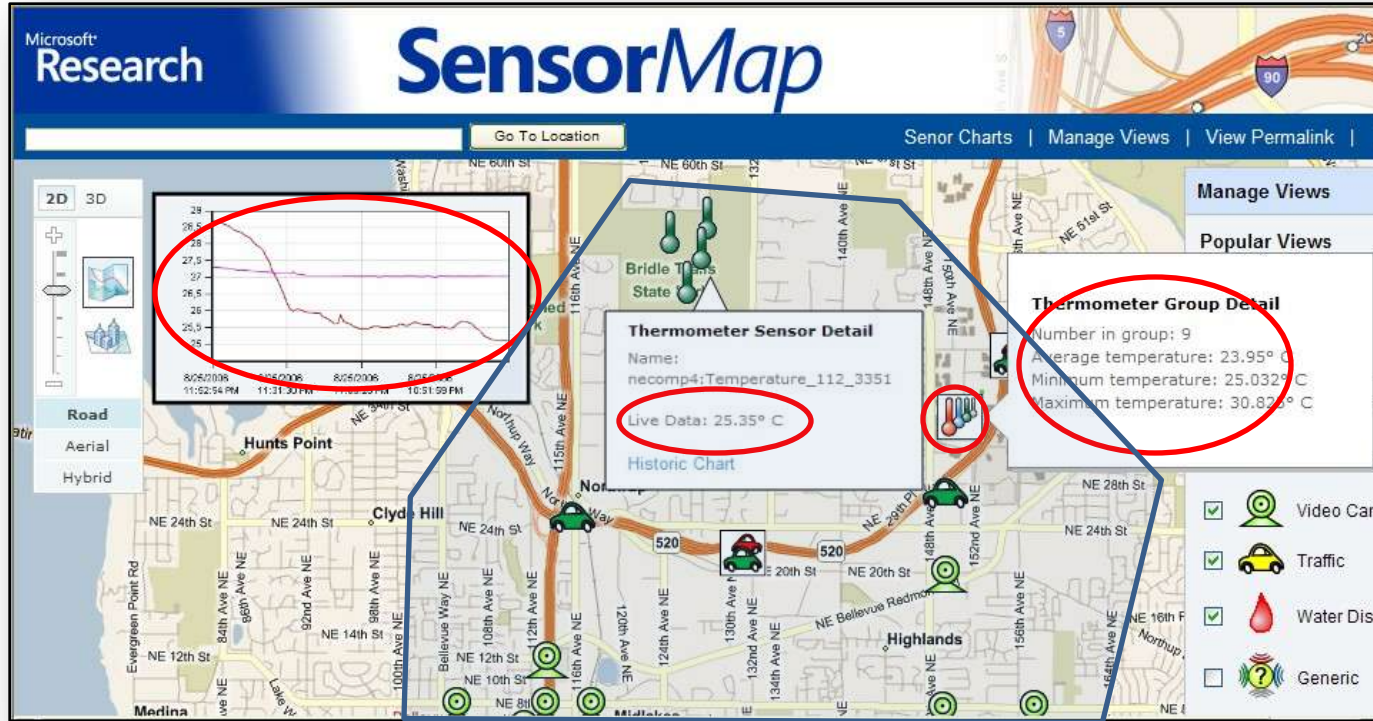
- Real-time data streaming and processing



SensorMap

Portal for finding sensors, eye-balling sensor data, and manage sensors

<http://atom.research.microsoft.com/sensormap>

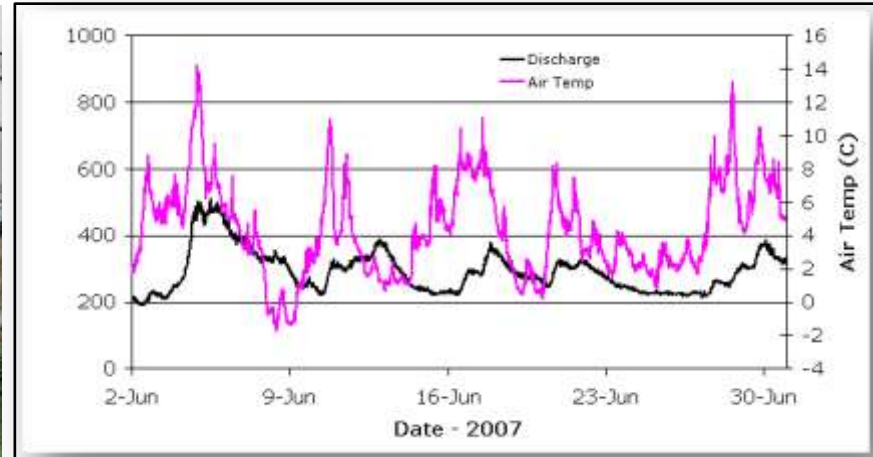


Sensors as Icons
Show real-time
and archived data

Search sensors
based on
geography, type,
keywords

Aggregate live data
at different zoom
levels

3D and Custom Visualization



Manage Sensors on SensorMap

Click directly on map to add sensors



Fill out form with sensor metadata

Publish Sensor

Sensor Name

Sensor Type*
Video Camera

File Type

Latitude

Longitude

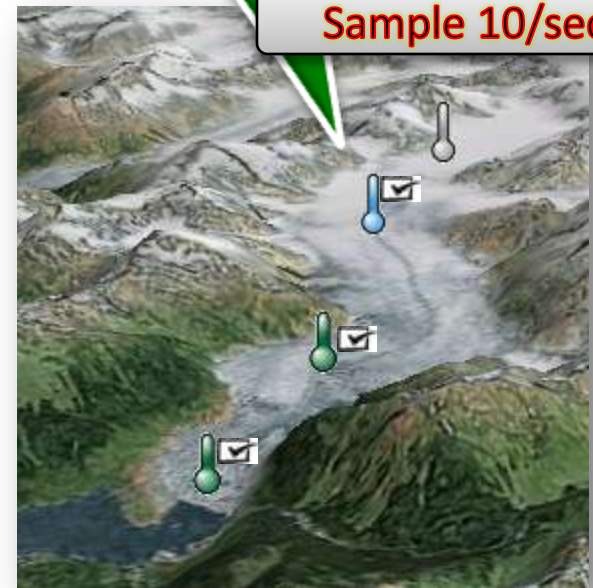
Real Time URI

Keywords (optional)

Sensor Description (optional)

* SensorMap only allows publishing of video and generic sensors. More sensor types may be supported soon.

Select multiple sensors and send command



Outline



Case Study

- SeaMonster: Glacier, hydrology, and oceanographic exploration
- SensorMap Demo



SenseWeb Architecture

- Global or selective sensor stream sharing

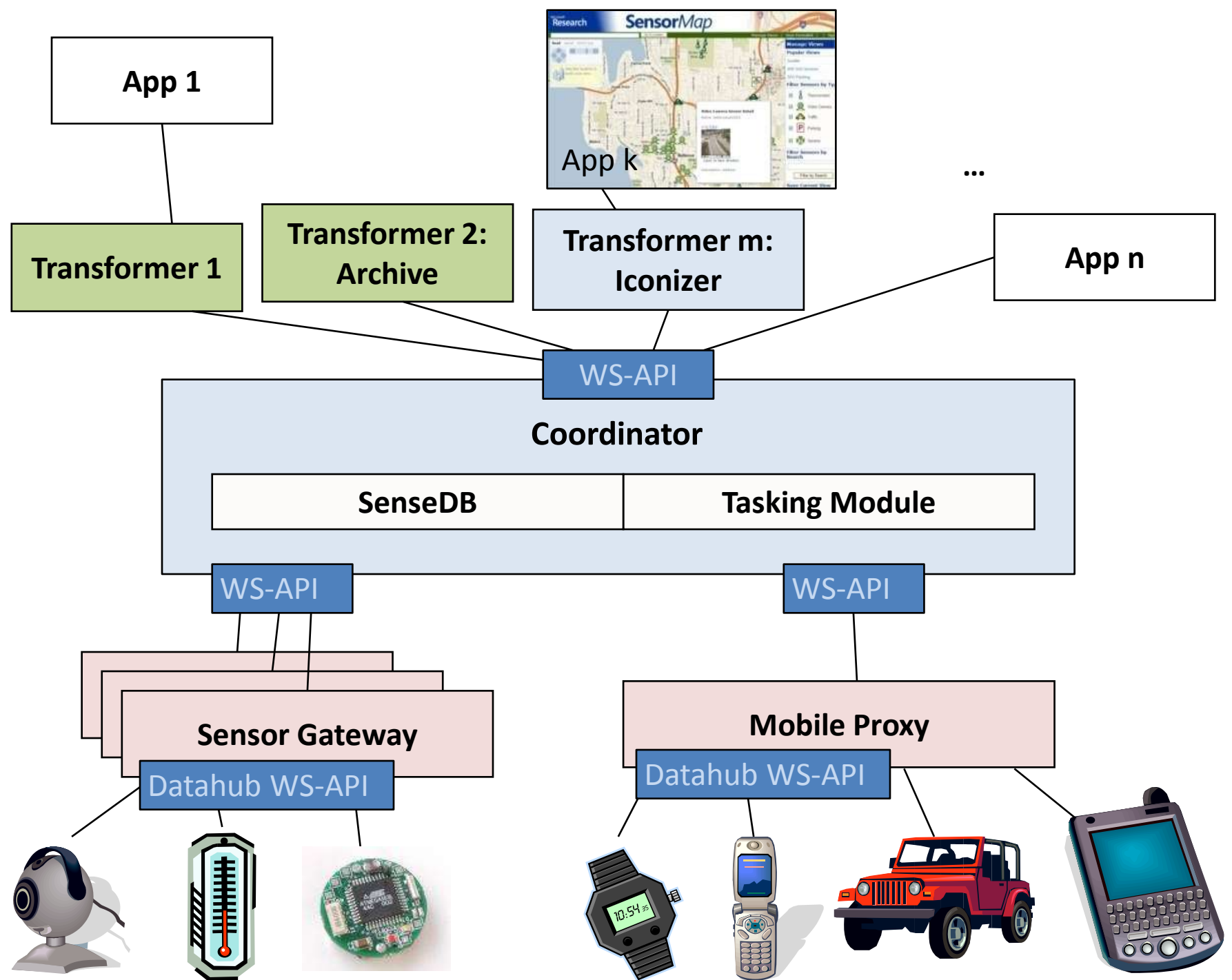


Usage Examples

- Projects using SenseWeb

Architecture Design Challenges

- Heterogeneity
 - Resource capability: bandwidth, power, computation
 - Willingness to share
 - Measurement accuracy
- Scalability
 - Streaming all raw data from all sensors to all applications not feasible
- Security and Privacy
- Data Verifiability, Trust



Coordinator

```
graph LR; A[Accepts application sensing demands] --> B[Determines sensing task overlap]; B --> C[Distributes sensing tasks to selected sensors];
```

Accepts application sensing demands

Determines sensing task overlap

Distributes sensing tasks to selected sensors

Data Re-use

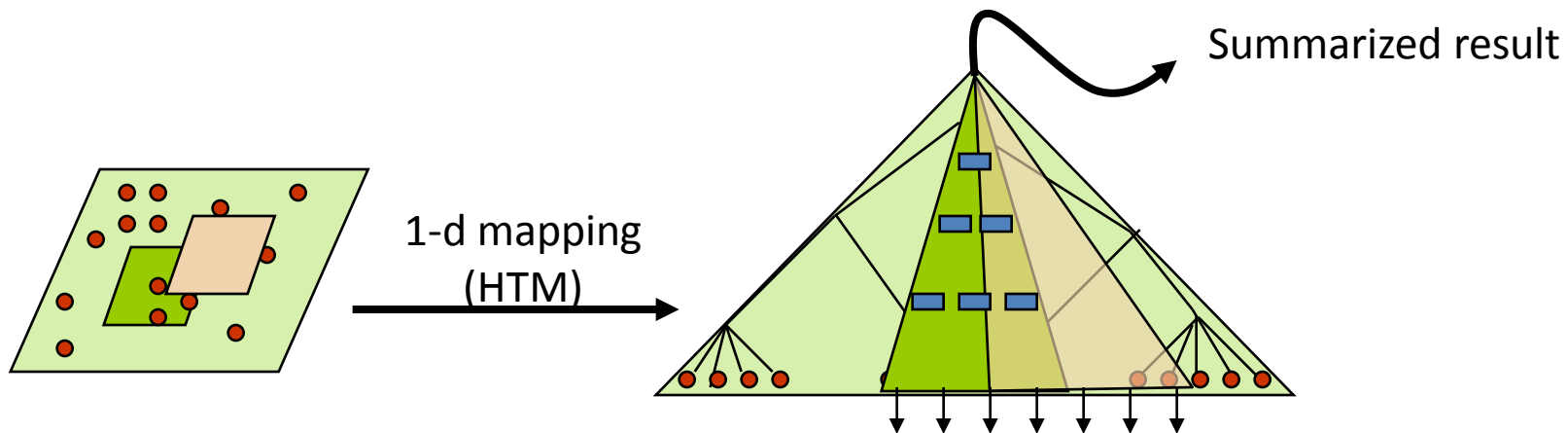
- Many applications may need similar data
 - Within a tolerable latency of each other
 - From overlapping region
- Can cache data and aggregates to reduce load on sensors and network
 - Overlap may be partial: computed aggregates may need partial new data

Query Model

```
SELECT Count(*)  
FROM Sensor  
WHERE sensor.location in Polygon(A) AND  
       sensor.time BETWEEN now()-10 and now()+10  
REPORTRATE 10 min  
SAMPLESIZE 50  
EVENT EventSpec(T>25)
```

COLR-Tree (COLlection R-Tree)

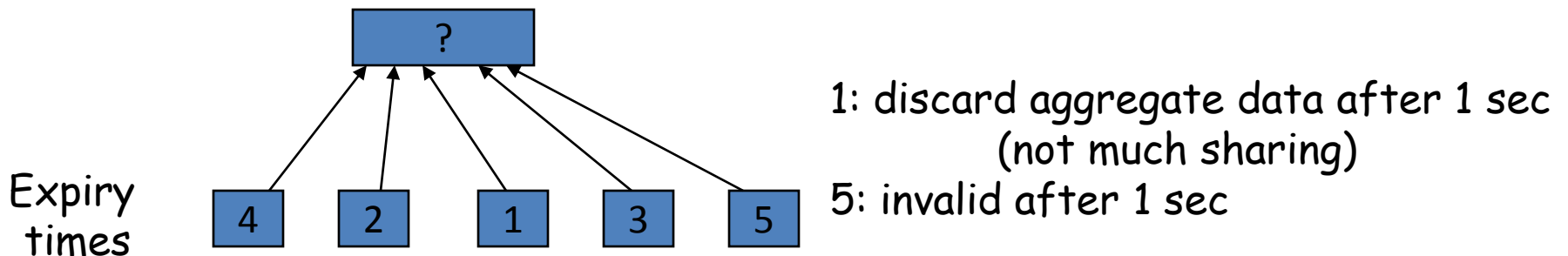
Index 2-D data with aggregates



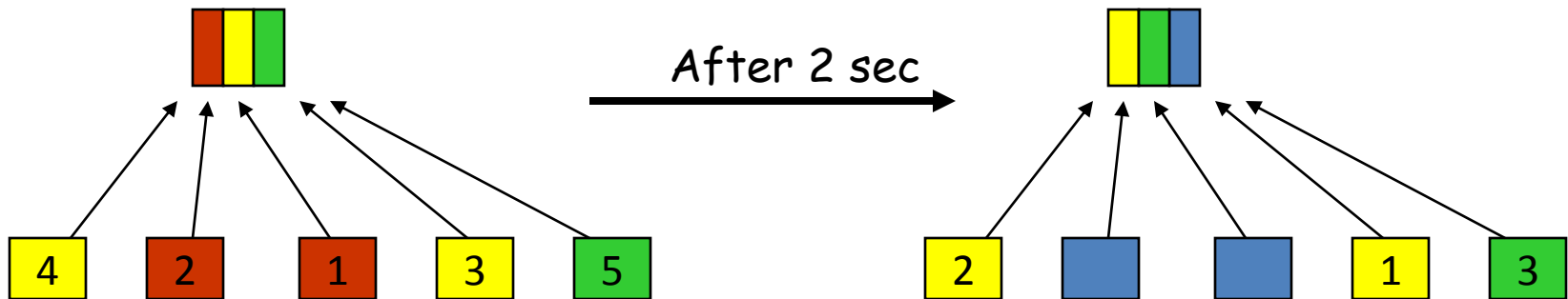
- Minimizing sensor access
 - Cached data may have skewed distribution
 - Sample more from non-cached region
- Implemented on MS-SQL Server: usable with all SQL server capabilities

COLR-Tree: Aggregates

- Challenge: temporal aggregation



Solution: slotted aggregation



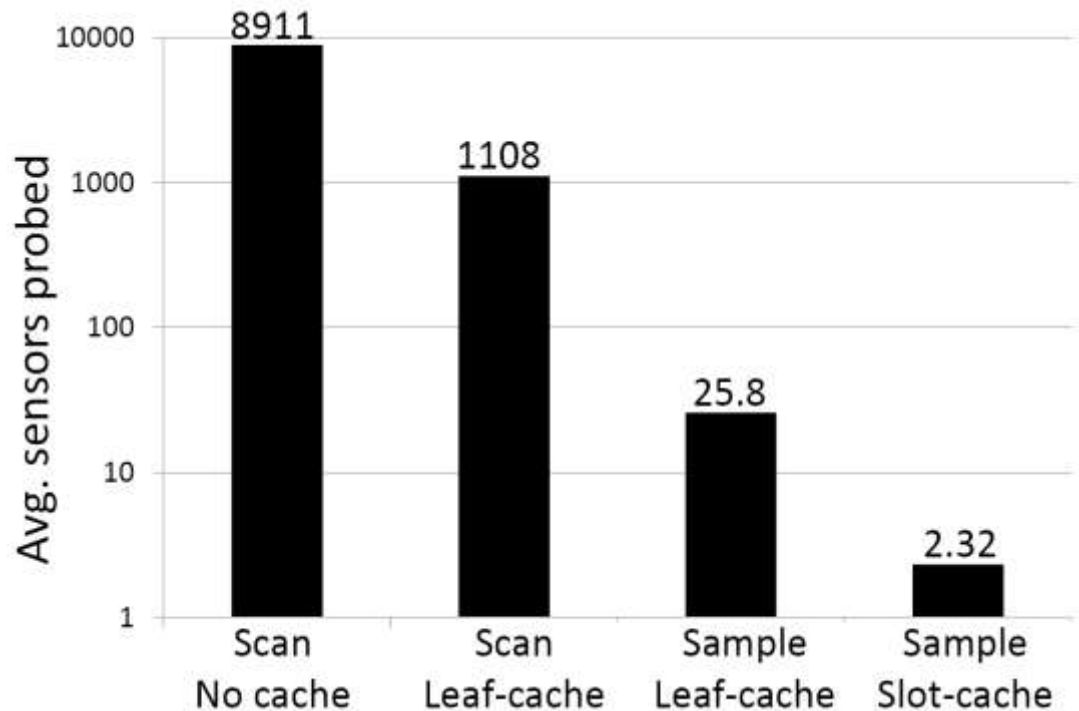
Spatial Sub-sampling

- Suppose sample size of R needed
- Layered sub-sampling along COLR-tree levels
- Partition R to achieve spatially uniform sample
 - $BB(i)$: area covered by i -th child, $c(i)$: data cached for i -th child, $w(i)$: sensors under i -th child, q : query region
 - For each child I at next level:

$$R(i) = R * \frac{w(i) - c(i)}{\sum_i w(i) * |overlap(BB(i), q)|}$$

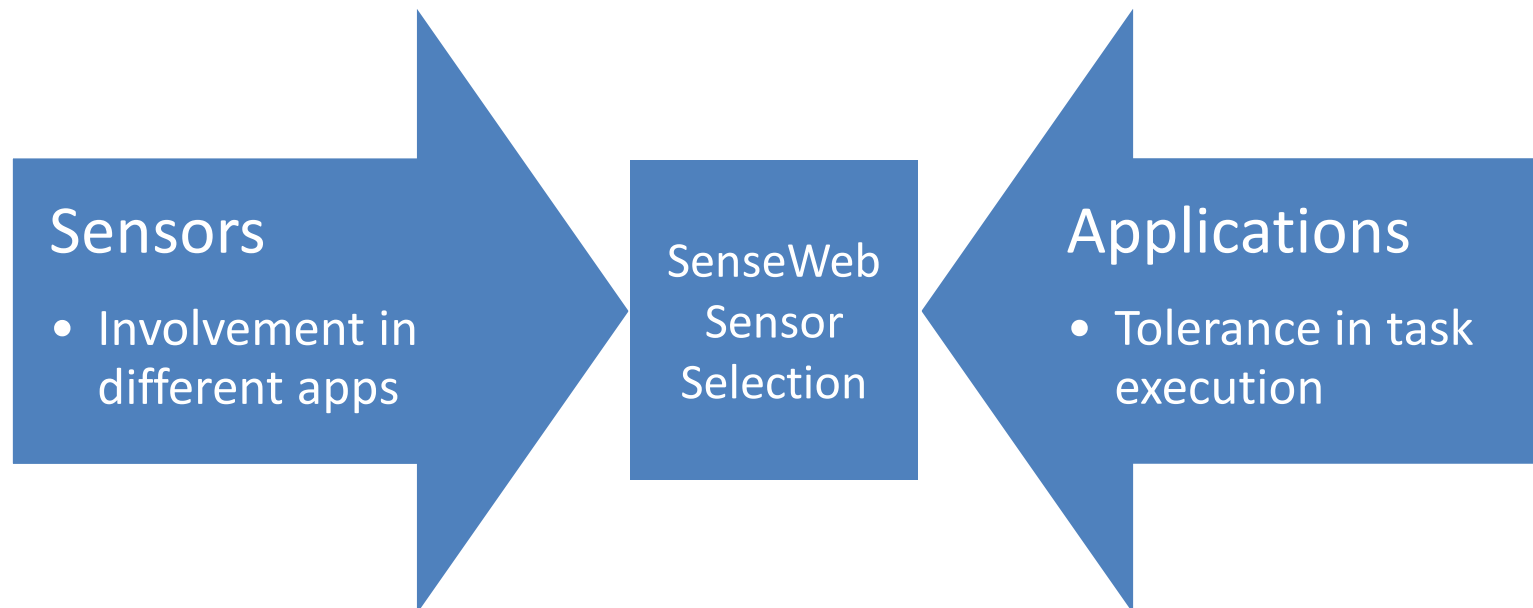
COLR-Tree Evaluation

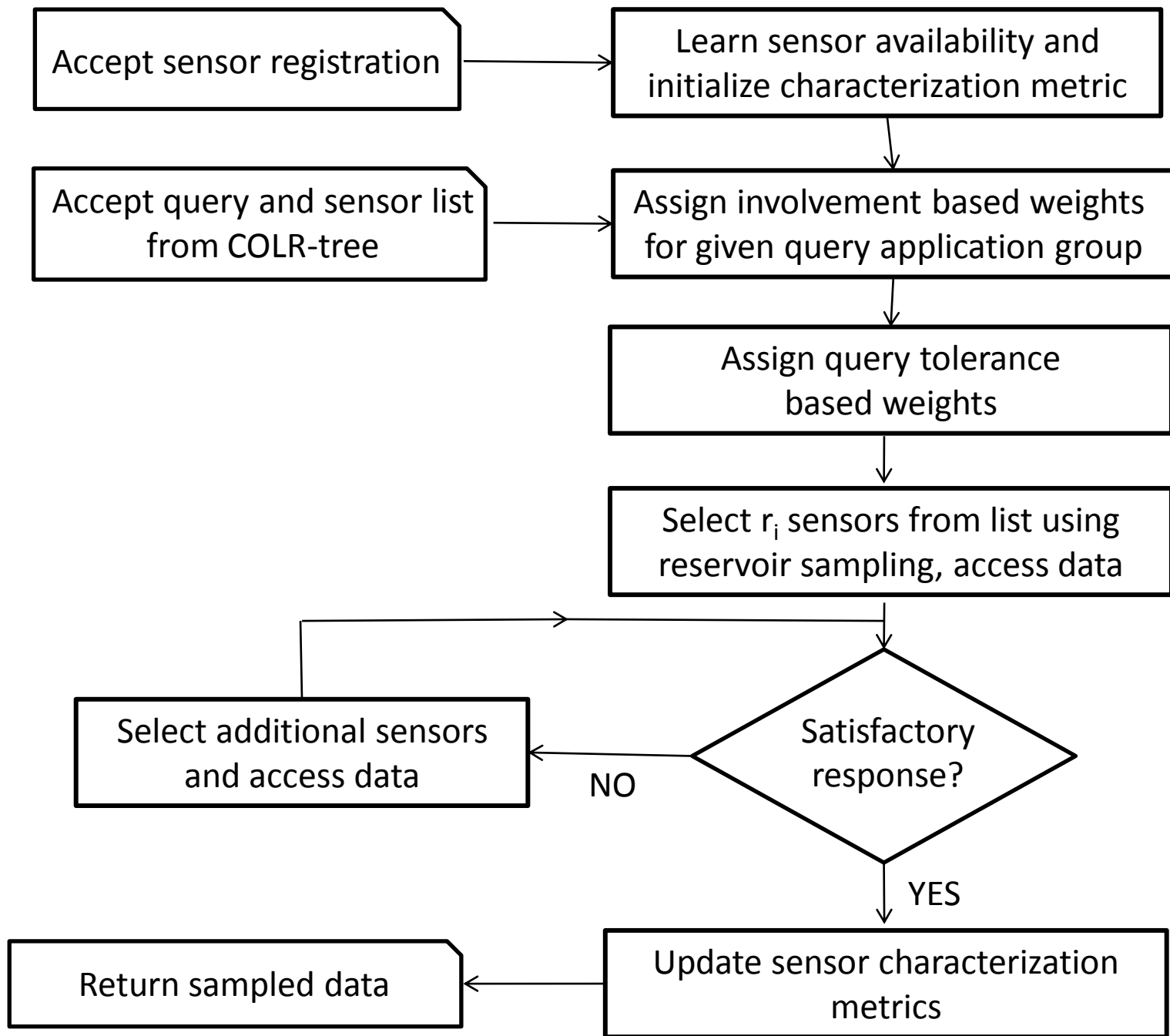
- Test data
 - 400K points from VE Yellow Pages
 - Regions queried: Virtual Earth usage trace



Tasking Heterogeneous Sensors

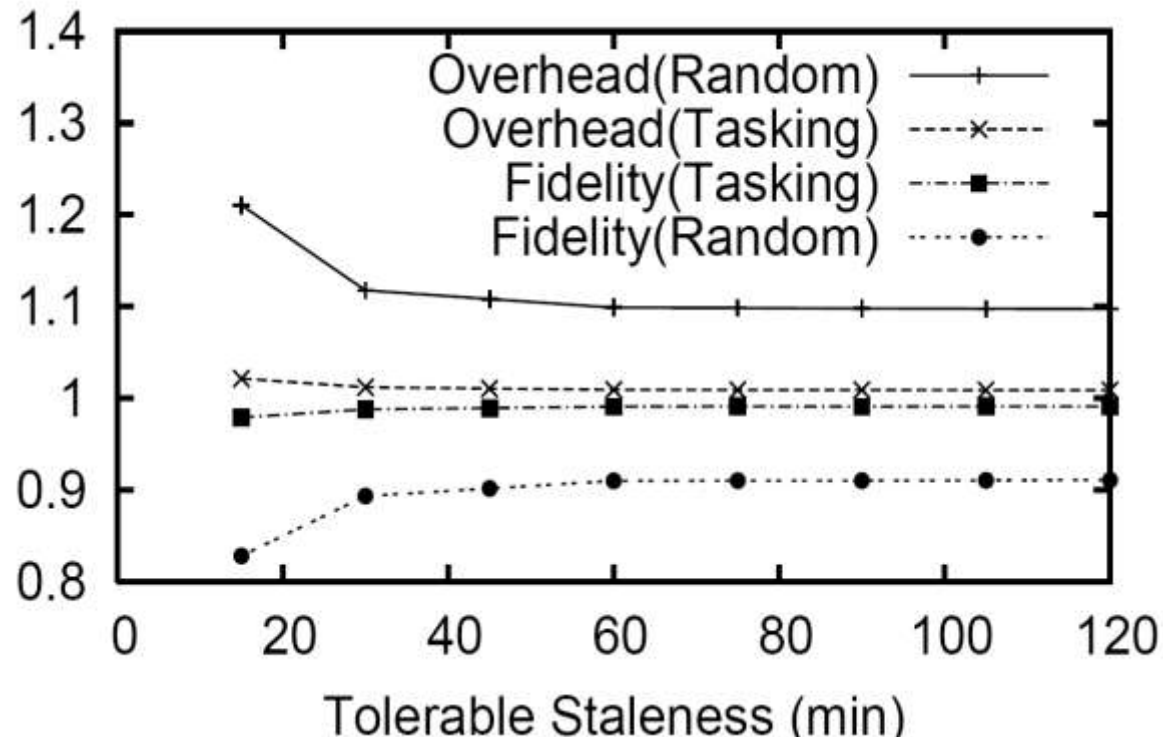
- Select uniformly rather than overloading the best sensors
- Leverage lower capability sensors when usable for a query
- Learn and adapt to sensor characteristics: availability, bandwidth
- Weighted reservoir sampling
 - Weighted random selection, with desired number of sensors





Tasking Algorithm Performance

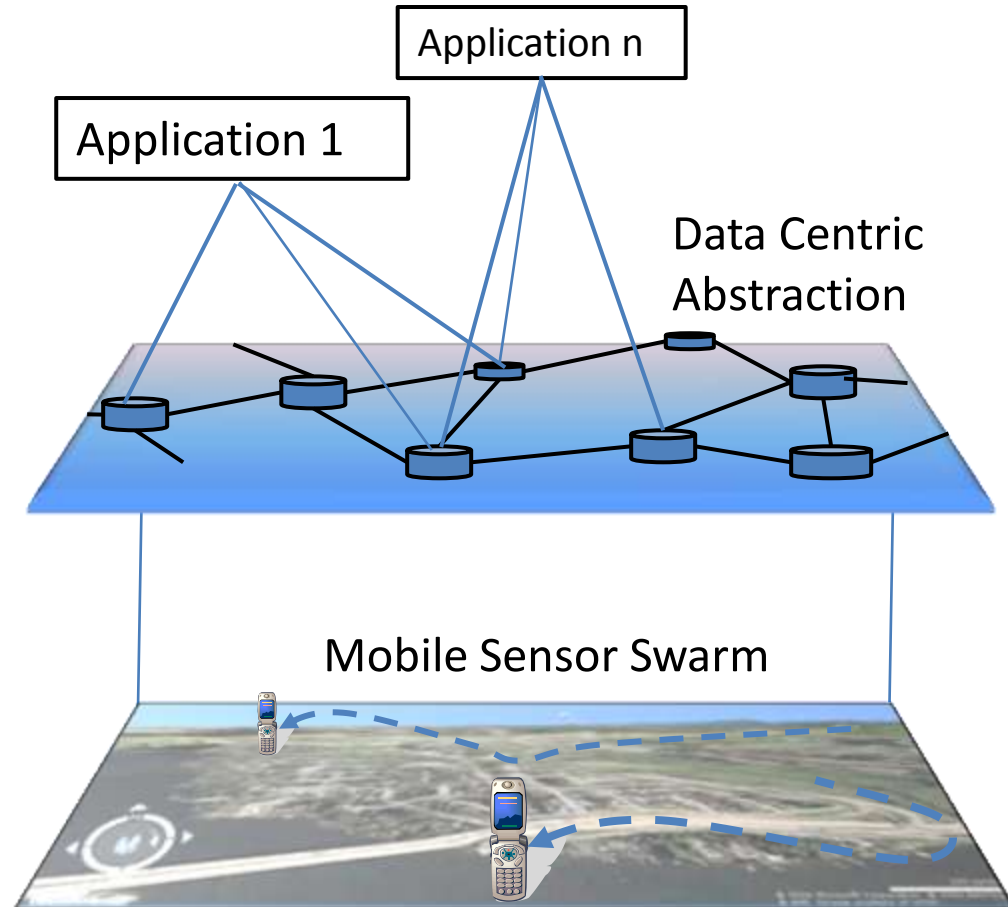
- Test on USGS stream water sensors
 - Random selection vs. Weighted reservoir sampling



Mobile Sensors in SenseWeb

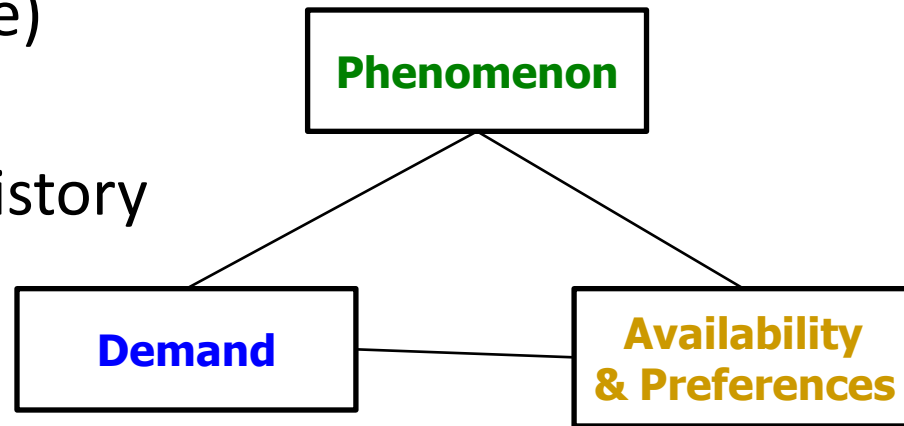
More coverage but
Hard for application to
track relevant devices

- **Solution:** data centric abstraction
 - Location based indexing
 - using GPS, cell-tower triangulation, content based location



Community Sensing

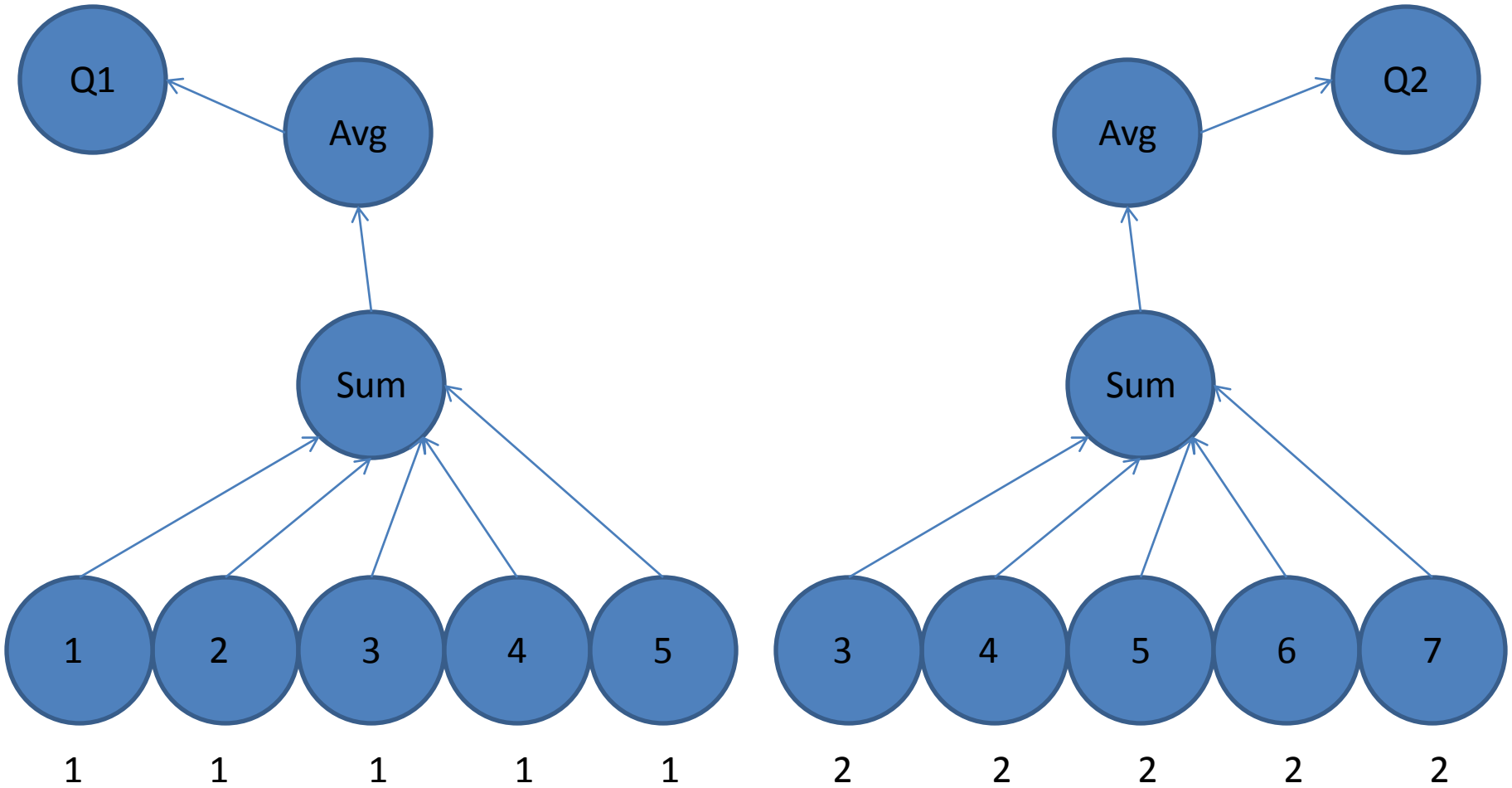
- Leverage roving sensors to measure urban/social phenomenon
 - **Information value** (collapse uncertainty)
 - **Demand** (“utilitarian” usage)
- Sensor availability
 - **Predict location** based on history
- Preferences
 - **Abide by preferences**
 - E.g., Frequency / number of probes, min. inter-probe interval
 - Other constraints: e.g., “Not near my home!”



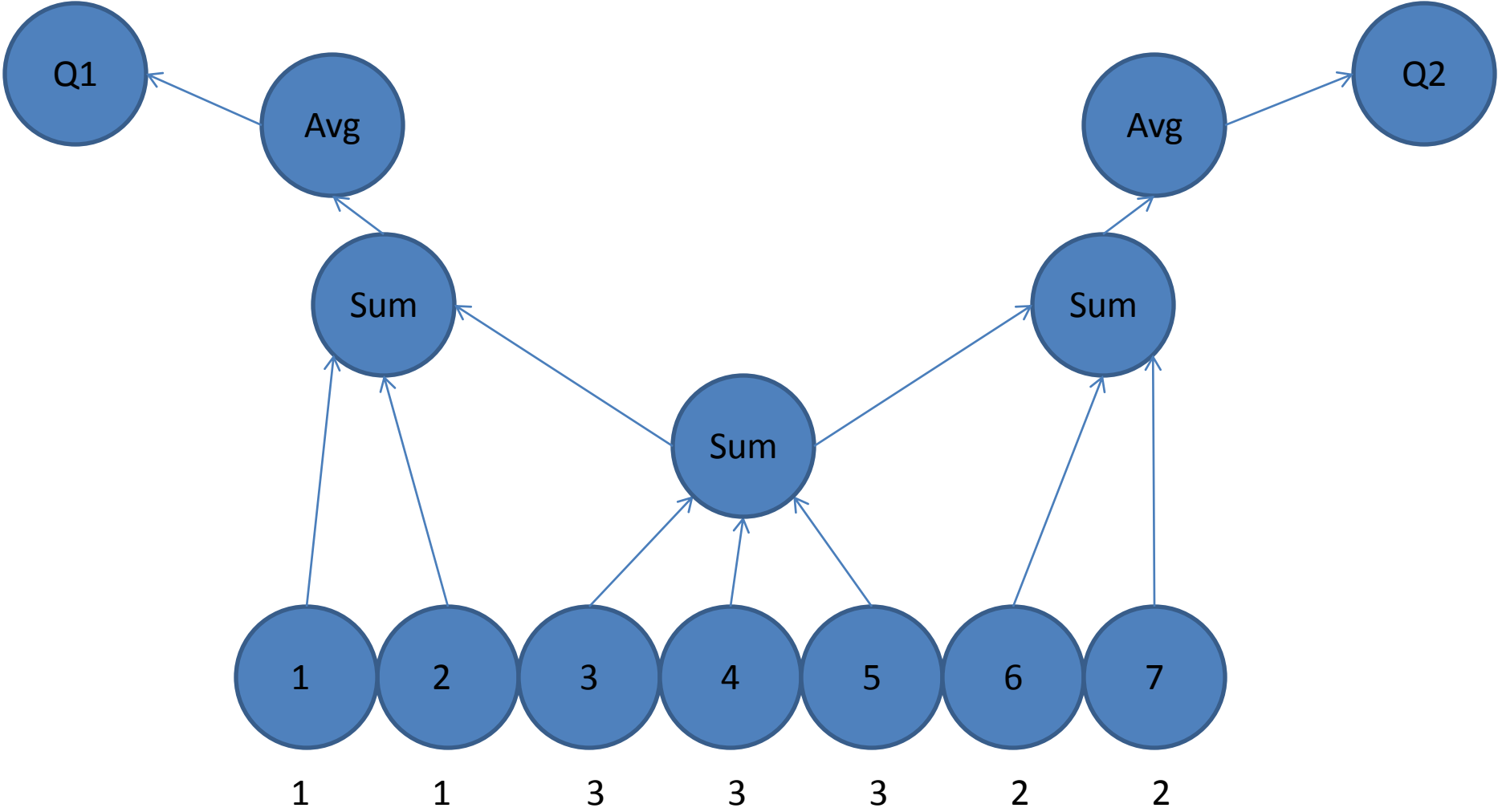
Shared Streaming

- Multiple apps. need data from similar sensors
- Problems
 - Sensor resources limited
 - Upload bandwidth, connectivity
 - Energy
 - Scalability of aggregation and streaming
- Solution
 - Cache data: identify relevant cache efficiently
 - Share aggregation and processing

Query DAG's



Optimized Shared Query DAG

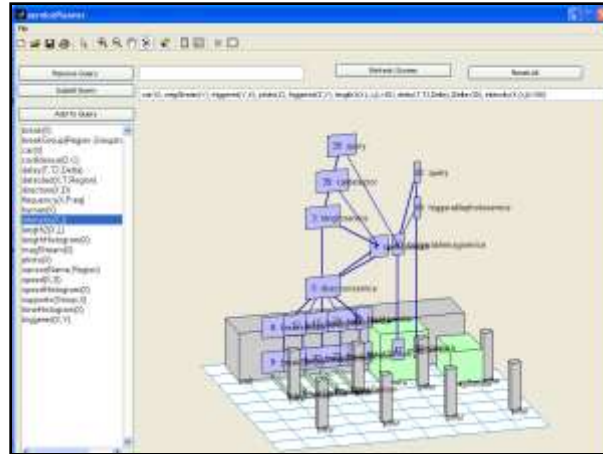


Tools for Sensor Contributors



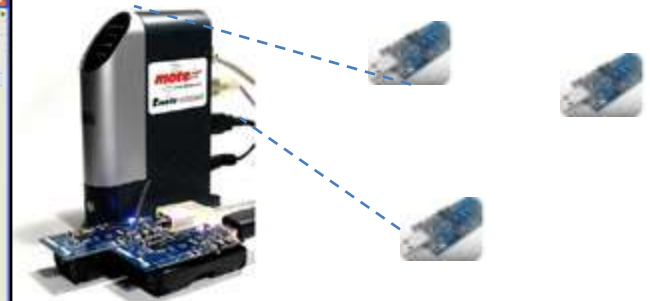
Client for cell-phones

- Allows users to take pictures
- Automatically uploads data to server
- Location stamps using inbuilt/Bluetooth GPS



For mote networks

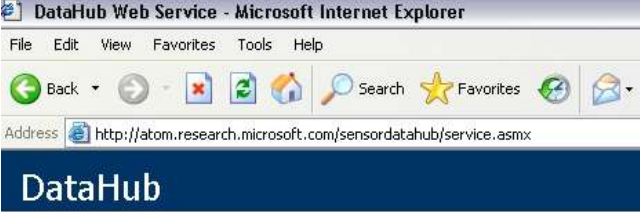
- Automatic data collection and sharing
- Simplified processing and application composition



Webcam data processing and sharing tool

Tools for Sensor Contributors

- Gateway for sensor contributors
 - Web service API: Datahub
 - Supports several sensor types via semantic hierarchy
 - Also archives sensor data
- Tools available for download
 - Tutorials available online



The following operations are supported. For a formal definition, please review the following:

- [GetAllSensorsByPublisher](#)
Return all sensors published by a publisher
- [GetLatestBinarySensorData](#)
Returns the latest image data reported by a sensor
- [GetLatestScalarSensorData](#)
Returns the latest scalar data reported by a sensor
- [GetLatestSensingTime](#)
Gets the latest timestamp of a sensor data
- [GetSensorDescriptionByName](#)
Get the meta data for a registered sensor.
- [IsDataYoungerThan](#)
Returns true if the sensor data is younger than specified milliseconds
- [RegisterSensor](#)
Register a sensor.
- [RemoveSensor](#)
Removes a sensor.

Current Projects

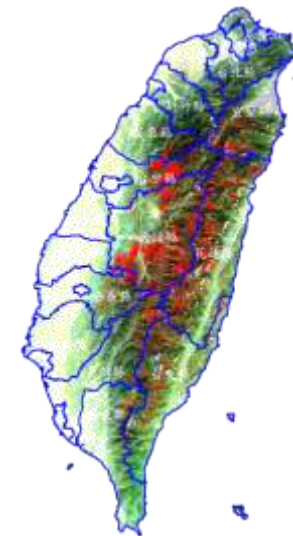
- Urban air quality
 - Vanderbilt, Harvard Univ



- Life Under Your Feet
 - John Hopkins Univ.



- Debris Flow
 - National Tsing Hua University, China

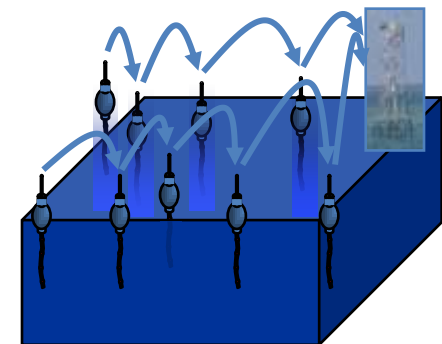


Current Projects

- National Weather
 - NTU Singapore



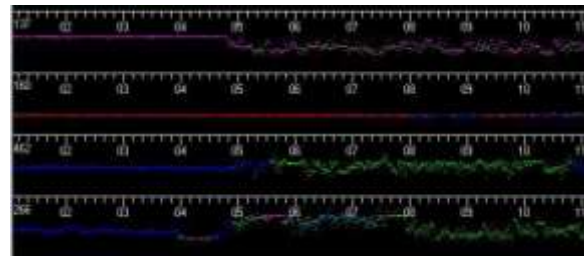
- Coral reef ecosystem in The Great Barrier Reef
 - U. Melbourne



Current Projects

- Bioscope: bird call streaming

- UIUC



- Swiss-Experiment

- EPFL, ETH, others



Applications Beyond Science

Community Fitness and Recreation

- Runners: Where are sidewalks broken? Construction finished on 24th St?
- Mountain Bikers: Average biker heart rate at Adams Pass on trail 320? [SlamXR]
- Surfer: What is the wave level and wind speed at Venice Beach now?

Real Time Information

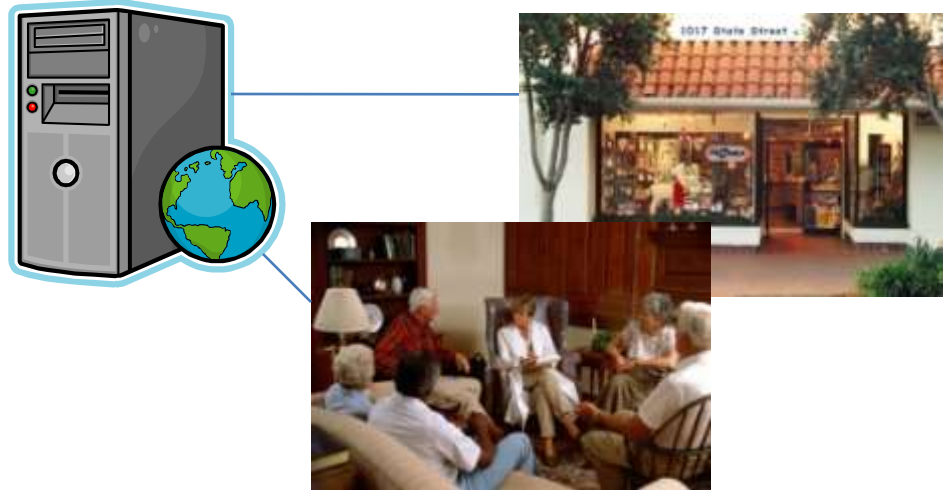
- Public initiated instant news coverage
- Road traffic monitoring from shared car GPS receivers

Business

- What are people doing tonight? Restaurant waiting times in downtown?
- Mall visitor activity and parking usage across franchise outlets worldwide
- Share pictures of suspected restaurant hygiene issues

Current Projects

- Urban-Net
 - Shopper interest
 - Assisted living
 - U. Virginia

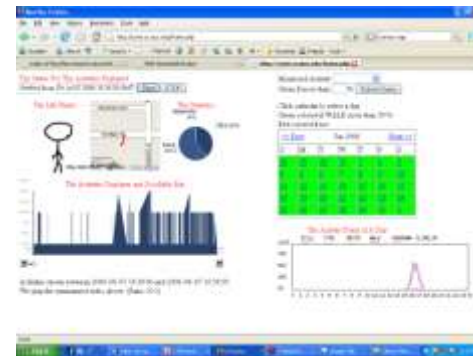


- Indoor events
 - U. Washington



Current Projects

- Large scale urban monitoring
 - Harvard
- Human Activity View
 - UIUC



Summary

- SenseWeb
 - Share sensor networks
 - Generic data and sensor management
- SensorMap
 - Interact with sensors in real time
 - Eye-ball sensor data
- MSRSense
 - Domain specific data analysis/mining
- Details: <http://research.microsoft.com/nec/senseweb/>